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ABSTRACT

Studies of children's verbal reasoning that are focused on the valid principles of conditional reasoning indicate that young children (1) draw inferences from logically unconnected semantically related statements; (2) arrive at conclusions on the basis of no presented evidence; (3) do not differentiate between definite and indefinite propositions; (4) never indicate uncertainty; and (5) do not comprehend conditionality. To investigate the invalid principles of conditional reasoning, further experiments were conducted. Conditional rules were presented through concrete instances from which children had to infer the rules, as opposed to the usual procedure of giving the rules verbally in the form of conditional statements. It was found that virtually all of the incorrect responses of third, fifth and sixth grade students were consistent with a biconditional interpretation of the rules (i.e., If x, then y and, if y, then x.). These results seem to point to a switch in children's reasoning patterns. Reasoning to logically correct conclusions with valid principles requires staying within given information. Rejecting an invalid inference requires going outside the given information. Research has shown that, when performing tasks requiring reasoning with valid principles, young children err by going outside of given information. However, in failing to reject invalid inferences, children err by staying within the given information. (Author/RH)

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Plausibility versus logical necessity
in children's verbal reasoning¹

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In a series of experiments (Bereiter, Hidi & Dimitroff 1979), we examined what children accept as conclusive evidence in their verbal reasoning. Our basic research device was a board game in which winning depended on correctly deciding whether to draw conclusions from verbal arguments or to get more evidence. The verbal arguments consisted of a conditional rule (e.g., If it is a sunny day, Joan goes to the beach) and a question (Did Joan go to the beach?). Evidence was given as either a critical or a peripheral clue. Critical clues were statements logically connected to the rule (e.g., It was a sunny day); peripheral clues were statements semantically related but logically unconnected to the rule (e.g., Joan loves to swim). Our findings may be summarized as follows:

(1) When given logically connected statements (i.e. conditional rule, question and critical clue), young children drew much the same kinds of inferences as older children and adults. However, young children also drew inferences from logically unconnected semantically related statements (i.e. conditional rule, question and peripheral clue), while older children were much less inclined to do so.

(2) Children in grade 2 showed a strong tendency to think that they knew the answers to the logic problems before they heard any clues and thus arrived at conclusions on the basis of no presented evidence at all --

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that is, after having been given the conditional rule and the question only. They frequently imported reasons from outside the argument from factual knowledge or fantasy to justify their inferences (e.g., Yes, Joan did go to the beach; her brother was trying to teach her how to swim).

(3) Second graders did not differentiate between definite propositions ("If...then...", "When...always...", etc.) and propositions that were rendered indefinite by the use of qualifiers such as "usually," "almost always," and "likes to." Although performance improved with age, children up to age 12 still showed an inclination to draw definite inferences from indefinite propositions.

(4) Many children of age 7 and 8 showed a lack of appreciation of conditionality as it is normally expressed. Thus they treated hypothetical statements of the form, "If p , then q ," as if asserting that p and q were both true.

The results showed a fairly dramatic shift between the ages 7 - 14 in the tendency to discriminate between logically connected and logically unconnected propositions. By responding indiscriminately to these two types of arguments, younger children demonstrated that their reasoning is not guided by a deductive process in which conclusions are reached on the basis of logical necessity, but by linking propositions together which seem to belong to the same general schema. It should be remembered that both the logically connected and logically unconnected statements contained elements that might be perceived as belonging to the same general schema -- the only difference between them being that the logically connected sentences had the additional property that they could support logically necessary conclusions.

Children over age 8 stayed within the given information and did not justify their conclusions on the basis of other related ideas. However, the ability to distinguish between logically connected and logically unconnected information appears to develop gradually across school years. In particular, it appears that children do not make the distinction between propositions which establish a conclusion as certain (i.e. logically necessary), and those which only establish it as highly probable until adolescence.

Our experiments suggest that younger children never indicate uncertainty and that only with increasing age do children develop an understanding of the precedence that logically certain conclusions take over plausible ones. Thus, the concept of necessity may develop first as a broad category in which all plausible conclusions belong and which eventually narrows down to logical certainty.

It may be noted that in the experiments reported so far, we looked only at the valid principles of conditional reasoning (basic understanding and contraposition). These principles have but one logically necessary conclusion each, which may be reached through both conditional and biconditional interpretations of the conditional rule. (Biconditional propositions express reversible, two-way implications.) Thus, in order to respond correctly, subjects did not have to recognize that the conditional rule is asymmetrical and not reversible.

In another set of experiments that we want to report here (Hidi 1976), we were concerned with the invalid principles of conditional reasoning (inversion and conversion). These principles have two logically

possible conclusions; to reach these conclusions subjects must recognize that the conditional rule expresses a non-symmetrical relation between p and q which is not reversible. There is much evidence of childrens' faulty performance on this type of reasoning task (Ennis 1971, Matalon 1962, O'Brien, Shapiro and Reali 1971, Peel 1967, Sanner 1974, Taplin, Staudenmayer and Taddino 1974, etc.), and practically the whole body of research conducted in this area supports the conclusion that children interpret the conditional rule as if it was biconditional.

It is our contention that children's tendency to consider conditional relations reversible is intimately related to their inability to distinguish logically or empirically certain propositions from plausible ones. In order to demonstrate this fundamental logical problem we had to make sure that subjects' faulty performances did not result from linguistic problems i.e., from their inability to interpret "If...then" statements appropriately. Thus, in our experiments, conditional rules were presented through concrete instances from which subjects had to infer the rules, as opposed to being given the rules verbally in the form of conditional statements. (This later method was used in almost all of the conditional reasoning research.)

The basic equipment used in the experiment was a small Hewlett-Packard 65 programmable calculator. One three keys covered with coloured tape (red, blue and green respectively) were included in the program. The rest of the keys were masked by a paper cover. The program specified the following rules:

If the red key is pressed, then 3 appears on the calculator display panel.

If the blue key is pressed, then 2 or 5 appears on the panel. Thus, whenever the red key was pressed number 3 appeared and when the blue key was pressed either a number 2 or a 5 might appear. The children observed the experimenter pressing the red and blue keys in a specified order to convey the above two rules. In addition, they were told that if something happened three times (in respect to a combination of a coloured key and a number), they could assume that it would always happen. No information was given regarding the green key.

The critical test occurred when children were told that a 2, 3, or 5 had appeared on the display and were asked to infer what key or keys could have caused the result. Since the outcome of pressing the green key was never established, it remained as a possible antecedent of any outcome. Thus, a correct response to what could have caused a 2 to appear on the screen was "blue or green." Among grade 3 children, 79% of responses to such questions were incorrect. In grade 5, 72% were incorrect, but by grade 6 this percentage decreased to 42%. Virtually all incorrect responses were consistent with a biconditional interpretation of the rules.

Another question produced an especially interesting manifestation of the younger childrens' inability to discriminate between what is certain and what is probable. Towards the end of the session, number 8 was introduced for the first time with the following sentence: "Imagine that number 8 appears on the panel. What key could have been pressed?" The children of all three grades had little difficulty in recognizing that only the green key could produce number 8. However, when asked later:

"What happens if I press the green key, what number could appear?", the majority of the two younger age groups insisted that number 8 would appear. Note that number 8 and the green key were never directly associated with each other.

Children were so adamant about this rule that in the subsequent interview they frequently recalled the rule ("the green key brings on number 8") as having been observed by them. Furthermore, subjects' faulty reasoning cannot be attributed simply to the cognitive overload due to additional memory space required to store the order of the antecedent and consequent of the asymmetrical implications. Subjects clearly demonstrated their ability to recall the terms (antecedent and consequent) in their appropriate order even when they reasoned biconditionally.

It seems that even though subjects remember the order of the terms, they consider the implicational rules reversible. In order to recognize that the rule is not reversible, subjects must first recognize that the plausible reversal of the rule is not necessarily true, and then consider alternative relations to those which are implied by the reversal of the rules. The calculator experiment indicates that most grade 3 and grade 5 children do not consider such alternatives even when they are concretely present, so long as their relevance has not been empirically demonstrated.

These results seem to point to an interesting switch in children's reasoning patterns. For logically correct conclusions with valid principles, one must stay within the given information. Bereiter et al (1979) showed that young children err by going outside of such data and that this tendency is overcome by age 10 or so. To reject an invalid inference, however, (i.e., avoid the fallacies of conversion and inversion), one must go outside the

given information to consider other possible antecedents (such as the green key in our experiment) which have not been specified. Children err by staying within the given information and thus consider only antecedents that have already been specified as logically relevant. This results in invalid rule reversals. The calculator experiment indicates that such invalid reversal is not purely a linguistic difficulty.

The ideas presented here are not too distant from those expressed by Lunzer (1975). Lunzer proposed that a necessary (but not sufficient) condition for most forms of advanced reasoning is acceptance of lack of closure (ALC). He differentiated between two types of problems: those in which unambiguous inferences may be reached through initial information allowing closure and those in which the initial information does not allow unambiguous inferences and which require acceptance of lack of closure for their solution.

Biconditional reasoning may represent the most adequate logical strategy that always leads to closure.

What we want to suggest is that subjects' premature closure, along with their inability to formulate abstract alternative relations on their own, is tied to their inability to distinguish plausible from logically certain conclusions. At the present state of knowledge, however, it is not clear whether these factors are causally related or parallel phenomena.